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Pervaporation performance of composite PDMS membrane for butanol production

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Interest for production of biofuels has been promoted by limited fossil fuel resources as well as due to environmental concerns and tightening legislation. Ethanol and biodiesel are already commonly used transportation biofuels, but also new alternatives are needed to fulfill the increasing demand. Butanol, having better fuel properties than ethanol, is a potential choice for renewable transportation fuel and feedstock chemical in the future.

Several different feedstock materials including agricultural and industrial by-products, wastes and residues can be used in the fermentation process of butanol. Biomass is pretreated and hydrolyzed to obtain monosaccharides for fermentation. Anaerobic acetone-butanol-ethanol (ABE) fermentation process includes two phases. At first, sugars are converted to acetic and butyric acids, carbon dioxide and hydrogen by clostridial bacteria. In the second phase, bacteria utilize acids to produce acetone, ethanol and butanol. Products are separated from the fermentation broth during or after the fermentation step. There are still some limitations and process development is needed in order to gain a feasible industrial scale production process. The main challenges are cost of feedstocks, low product yield from fermentation and costly product recovery and purification techniques. Because butanol is harmful for bacteria cells, integrated product separation is highly favourable for the removal of butanol during the fermentation and thereby increasing the yield. Pervaporation as a separation technique has no negative effects on fermentation process and is cost- and energy-efficient as compared to other methods such as distillation, gas stripping, liquid-liquid extraction or membrane distillation.

The aim of this work was to investigate the performance of the polydimethylsiloxane (PDMS) membrane with the support layer of polyacrylonitrile (PAN) for the removal of acetone, butanol and ethanol from dilute aqueous solutions. The membrane was manufactured by Pervatech, the Netherlands. The effect of feed composition was tested by using first binary aqueous mixtures of acetone, butanol and ethanol, followed by experiments with different kind of aqueous ternary mixtures, and finally a quaternary ABE-water mixture. All of the used mixtures were dilute aqueous solutions with concentration of organic compounds below 5 wt% to simulate the product concentration range typical for the ABE fermentation process. At constant feed solution temperature of 50 °C, the membrane permselectivity was found to be in the order of acetone ≈ butanol > ethanol (Figs. 1 and 2). Difference in the separation of acetone and butanol was minor, especially within concentrations below 1 wt%. Partial flux of ethanol was much lower compared to other compounds. Results indicate that the tested membrane has potential to be used in the ABE fermentation process.

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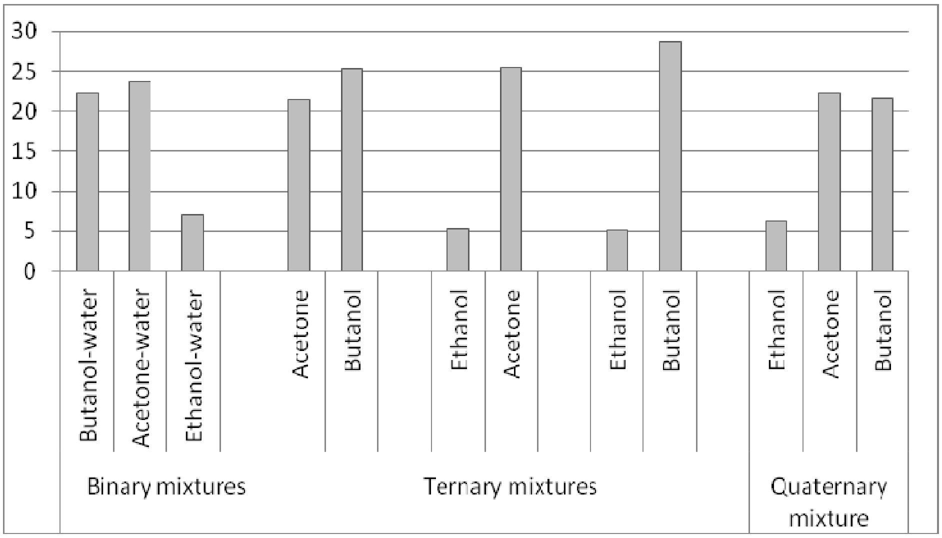

Fig. 1. Separation factors of different feed mixtures.

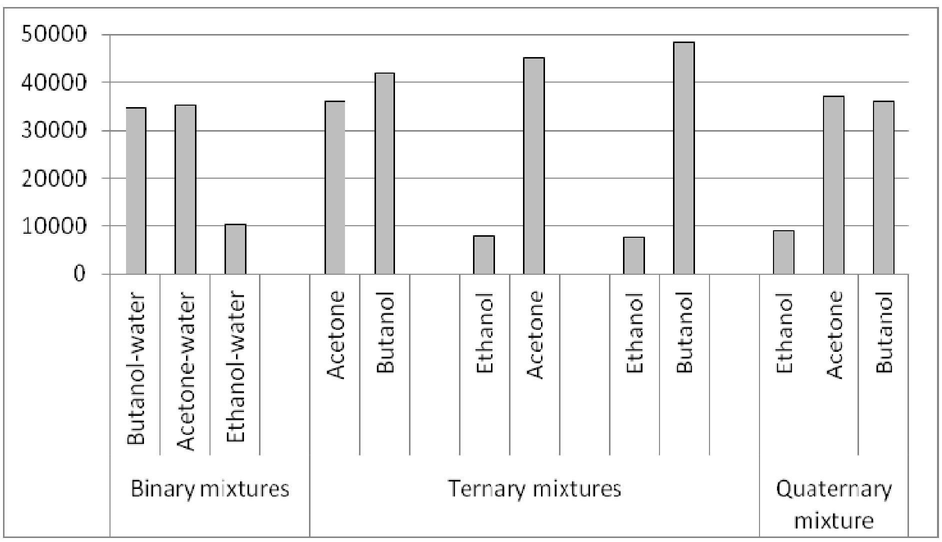

Fig. 2. Pervaporation separation indexes of different feed mixtures.

Keywords: Pervaporation, Butanol, Acetone-butanol-ethanol (ABE) fermentation, Polydimethylsiloxane (PDMS) membrane